

[0039] **What Is Claimed Is:**

1. A Lewis acid ionic liquid composition comprising:
 - (a) a cation selected from ammonium, sulfonium, and phosphonium cations wherein said cation has less than 14 total carbon atoms; and
 - (b) an anion having the formula $\text{Al}_y\text{R}_{3y+1}$ wherein y is greater than 0 and R is independently selected from the group consisting of an alkyl group and halogen group with the proviso that when the cation is triethylmethyl ammonium the anion is selected from aluminum bromide, or aluminum iodide.
2. The composition of Claim 1 wherein the cation is tetralkylammonium.
3. The composition of Claim 1 wherein the anion is an aluminum chloride anion.
4. The composition of Claim 2 wherein one or more of the alkyl groups is substituted with an ether group.
5. The composition of Claim 2 wherein one or more of the alkyl groups is substituted with one or more halogens.
6. The composition of Claim 1 wherein the cation is selected from trimethylethyl ammonium, bis(N-alkyl) substituted piperidinium, trimethyl chloromethyl ammonium, trimethylbutyl ammonium, and tributyl methyl ammonium.
7. The composition of Claim 6 wherein the piperidinium is substituted with a methyl and one group selected from the group consisting of $-(\text{CH}_2)_2\text{OMe}$, butyl, and propyl.
8. The composition of Claim 6 wherein the anion is an aluminum chloride anion.
9. The composition of Claim 7 wherein the anion is an aluminum chloride anion.
10. The composition of Claim 1 further comprising a salt comprising quaternary ammonium cations and halide anions.
11. A process for preparing an ionic liquid composition comprising reacting a cation source with an anion source to form an ionic liquid that comprises:
 - (a) a cation selected from ammonium, sulfonium, and phosphonium cations wherein said cation has less than 14 total carbon atoms; and
 - (b) an anion having the formula $\text{Al}_y\text{R}_{3y+1}$ wherein y is greater than 0 and R is independently selected from the group consisting of an alkyl group and a halogen group with the

proviso that when the cation is triethylmethyl ammonium the anion is selected from aluminum bromide, or aluminum iodide.

12. The process of Claim 11 wherein the ratio of ammonium, sulfonium, or phosphoniumhalide with $\text{Al}_y\text{R}_{3y+1}$ is such that any heat produced by the reaction is controlled.

13. The process of Claim 11 wherein the ammonium, sulfonium, or phosphonium halide is in molar excess of the $\text{Al}_y\text{R}_{3y+1}$.

14. The process of Claim 11 wherein the $\text{Al}_y\text{R}_{3y+1}$ is in molar excess of the ammonium, sulfonium, or phosphonium halide.

15. The process of Claim 11, further comprising contacting the cation source with a solvent and removing heat generated during reaction of the cation source and anion source by evaporation and condensation of the solvent.

16. The process of Claim 15 wherein the solvent is selected from the group consisting of cyclohexane, an alkane, and toluene.

17. An ionic liquid composition, comprising:

(a) a cation selected from the group consisting of ammonium, sulfonium, and phosphonium cations, said cation having between 5 and 11 total carbon atoms and containing no heterocyclic structures, said cation being non-tetrahedrally symmetric; and

(b) an anion having the formula $\text{Al}_y\text{R}_{3y+1}$ wherein y is greater than 0 and R is independently selected from the group consisting of an alkyl group and halogen group with the proviso that when the cation is triethylmethyl ammonium the anion is selected from aluminum bromide or aluminum iodide;

and wherein the anion and the cation are present in a molar ratio with of range of between about 1.8 moles of anion per mole of cation to about 2.2 moles of anion per mole of cation.

18. An ionic liquid composition, comprising:

(a) a cation comprising a pyrrolidine-based structure; and

(b) an anion having the formula $\text{Al}_y\text{R}_{3y+1}$ wherein y is greater than 0 and R is independently selected from the group consisting of an alkyl group and halogen group.

19. An ionic liquid composition, comprising:

(a) a cation selected from the group consisting of ammonium, sulfonium, and phosphonium cations, said cation being non-tetrahedrally symmetric;

- (b) a anion containing at least two aluminum atoms, the aluminum atoms being bonded together by an organic bridge to stabilize the chloroaluminate anion and inhibit leaching from the chloroaluminate anion.
20. The composition of Claim 19, wherein the organic bridge comprises an alcoxide group to inhibit leaching of aluminum trichloride during use.
21. The composition of Claim 19, wherein the organic bridge comprises an arene group to inhibit leaching of aluminum trichloride during use.
22. The composition of Claim 1, wherein the anion is a aluminum chloride anion, and wherein the cation is sourced from an ammonium salt selected from the group consisting of MeBu3N Cl, Me3PentylN Cl, Me3ButylN Cl, MeEt3N Cl, Me2Et2N Cl, Cl-CH2-NMe3 Cl, and N-methyl-N-Butyl Pyrrolidinium Cl.
23. An ionic liquid selected from the group consisting of N-alkyl substituted piperidinium heptachlorodialuminate, trimethyl chloromethyl ammonium heptachlorodialuminate, trimethylbutyl ammonium heptachlorodialuminate, and tributyl methyl ammonium heptachlorodialuminate.
24. A process for synthesizing an ionic liquid, comprising:
- (a) reacting a first reactant with an alkyl halide in an organic solvent, thereby forming a cation as a halide salt, the first reactant being selected from the group consisting of amine, phosphine, and mercaptan;
 - (b) adding heat to organic solvent to cause it to boil, thereby forming an azeotrope between the organic solvent and water;
 - (c) removing water from the mixture by azeotropic distillation; and
 - (d) contacting the halide salt with a chloroaluminate to form an ionic liquid.

25. The process of Claim 24, further comprising refluxing the solvent to remove at least a portion of heat generated by reaction.
26. The process of Claim 24, further comprising separating the solvent from the ionic liquid by liquid extraction.
27. The process of claim 24, further comprising separating the organic solvent from the formed ionic liquid by distillation under vacuum conditions.
28. The process of claim 24, further comprising removing a portion of the organic solvent from the mixture by distillation, removing impurities from the portion of the organic solvent, and recycling the portion of the organic solvent back into the mixture.
29. The process of claim 24, wherein the organic solvent is cyclohexane.
30. The composition of claim 19, wherein the anion has a structure that is selected from the group consisting of the following:

